# Meteoric layers in planetary ionospheres

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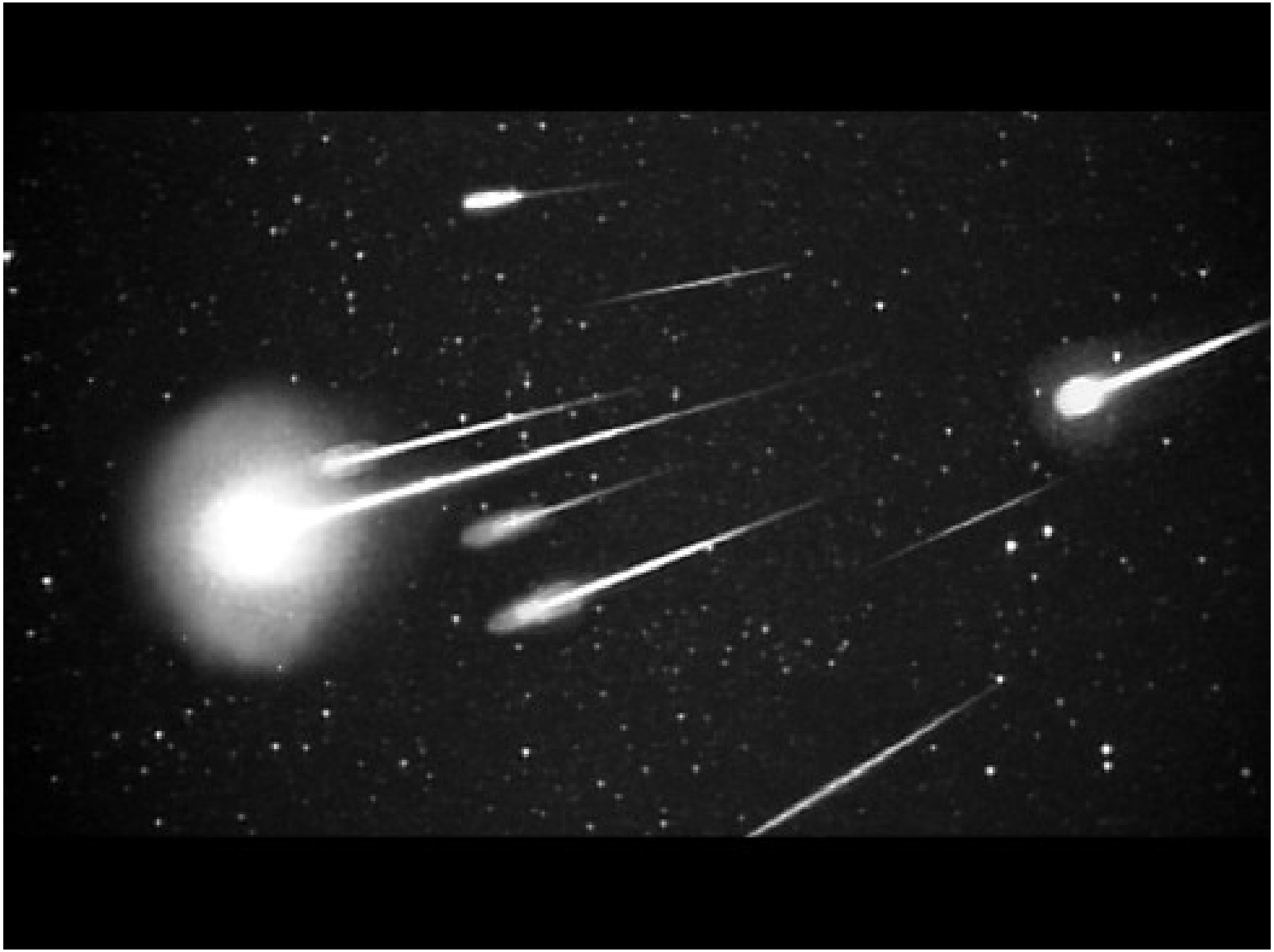
A fireball meteor in Earth's atmosphere augmenting metal ion densities in the ionosphere, as viewed from the International Space Station (ISS).

Credit: Ron Garan, ISS Expedition 28 Crew, NASA

Fig 1A of Withers (2012)



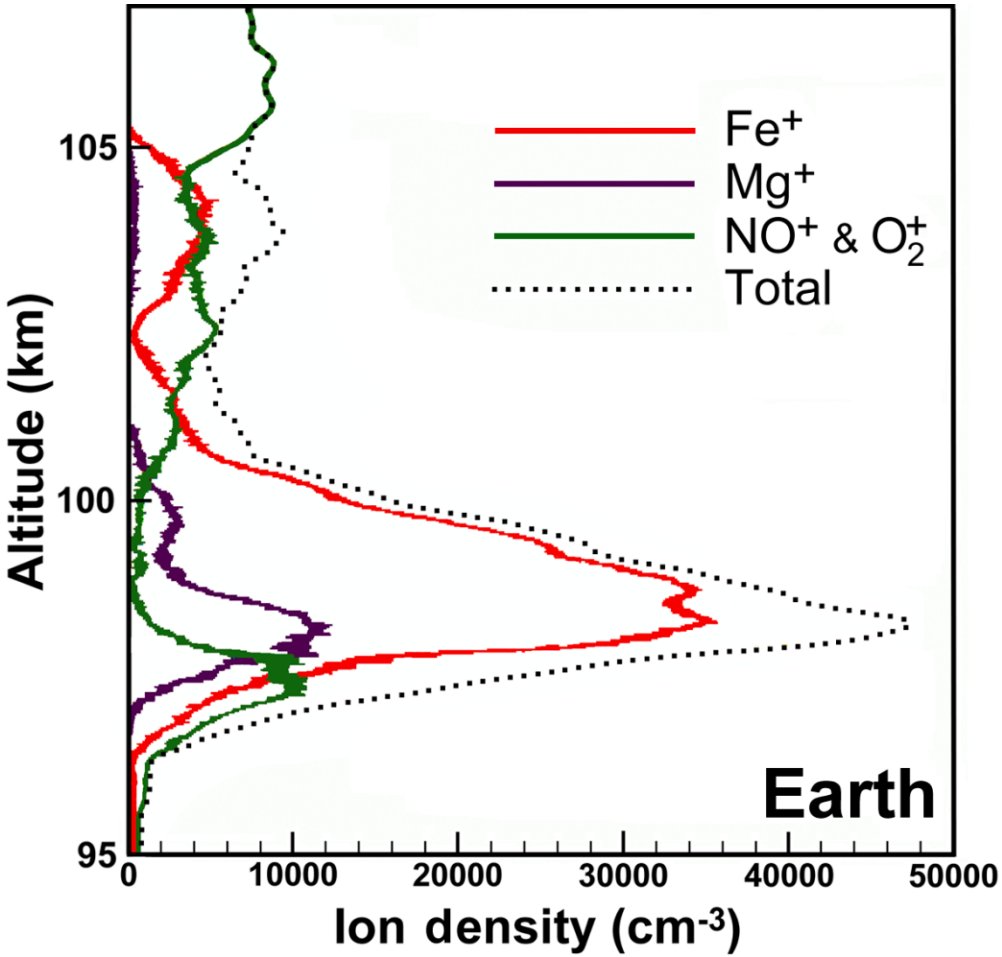
1999 Leonid storm as seen from Leonid Multi-instrument Aircraft campaign with 50 mm camera.
Photo: Shinsuke Abe and Hajime Yano, ISAS.

http://leonid.arc.nasa.gov/HDTV_LEO50mm-1.jpg


1966 Leonid storm as seen from Table Mountain Observatory, California, by James W. Young.
Photo: TMO/JPL/NASA.

http://leonid.arc.nasa.gov/66leonid1a.jpg

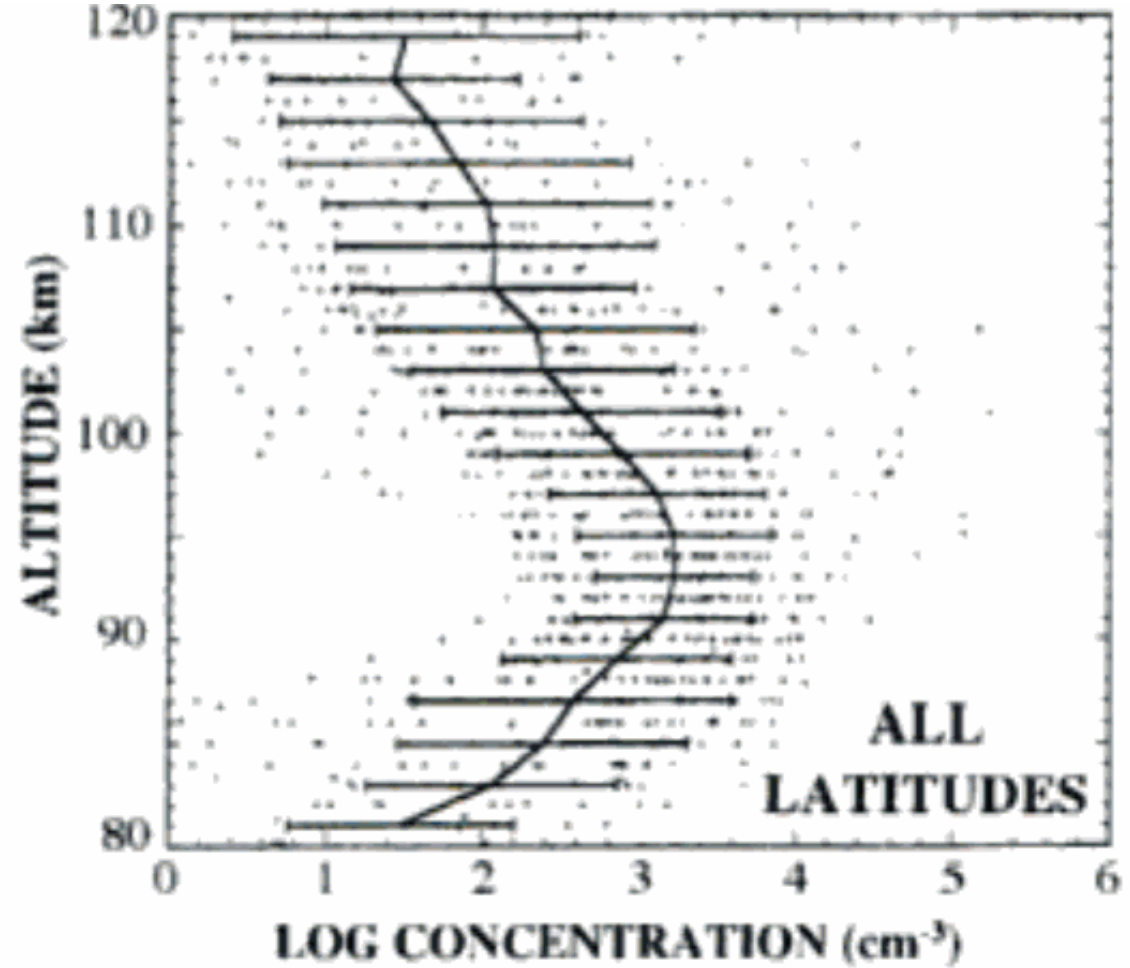
# Example of metal ions at Earth




Meteoric ion densities measured above Puerto Rico by a rocket-borne mass spectrometer. In these post-sunset measurements, photo-produced plasma ($NO^+$ and $O_2^+$) at these E region altitudes is sparse. Note the narrow width (about 2 km) of the meteoric layer and its large peak density of $5 \times 10^4$ $cm^{-3}$.

Reproduced from Figure 8.11 of Grebowsky and Aikin (2002)

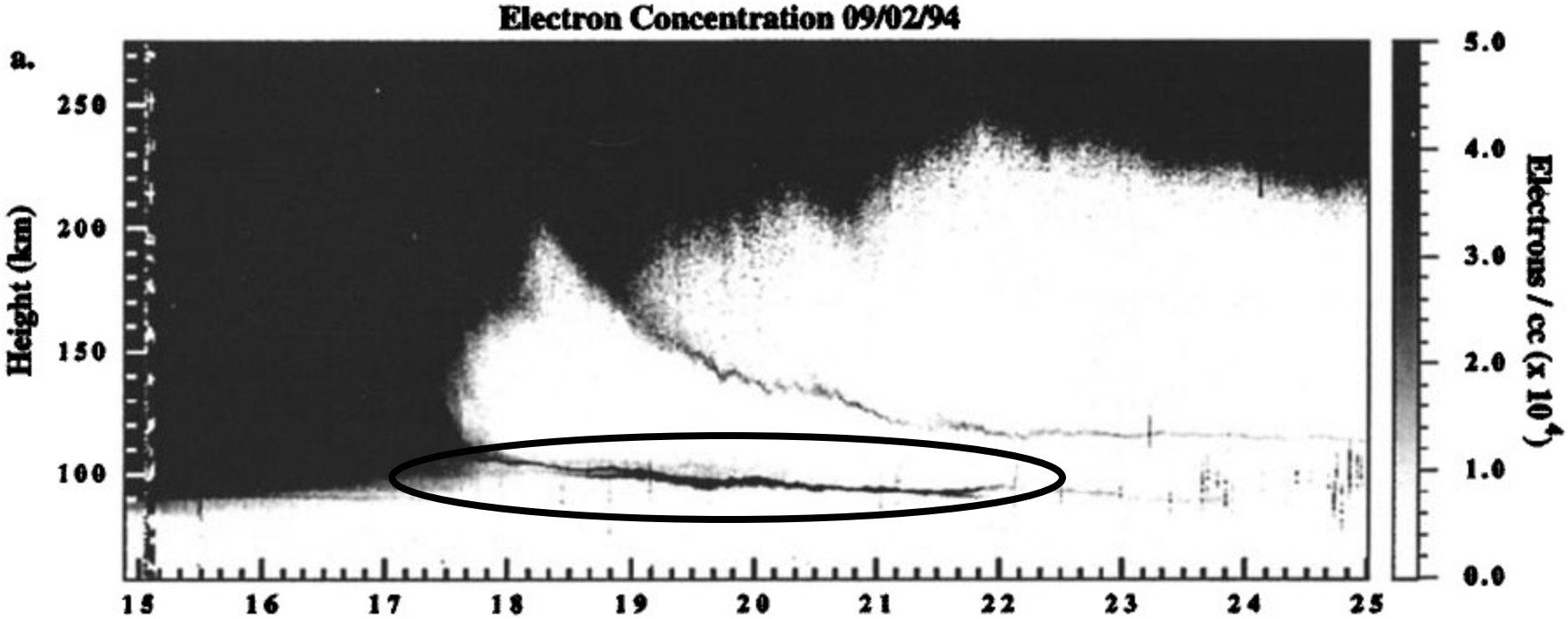
# Average profile at Earth




Average metal ion densities (total of all metal species) from many sounding rocket flights
There is more than an order of magnitude scatter in the concentrations

Fig 8.5 of Grebowsky and Aikin (2002)

# Sporadic E layer at Earth




Sporadic E = Dense layers of plasma at E-region altitudes that aren't related to normal E layer

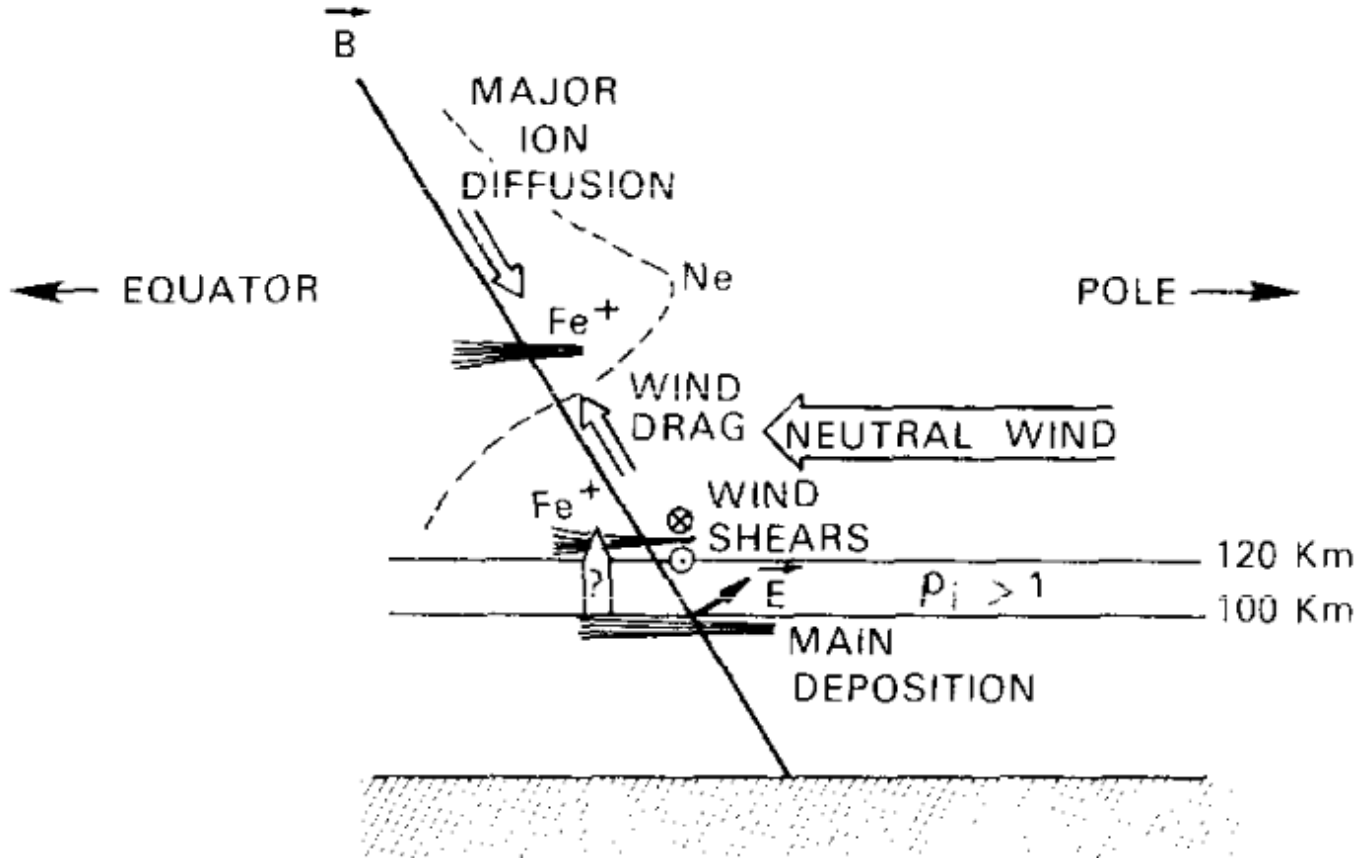
Plasma persists into night, requires long-lived ions – atomic metal ions

Formed by wind shear in strong, inclined magnetic field

Ionosonde data from Arecibo

Figure 2a of Mathews et al. (1997)

# Making narrow layers on Earth




Mechanism for producing narrow layers of metal ion plasma by wind shear in a magnetic field that is strong and inclined

Fig 5 of Grebowsky and Pharo (1985)

# Normal ionospheric profile at Mars

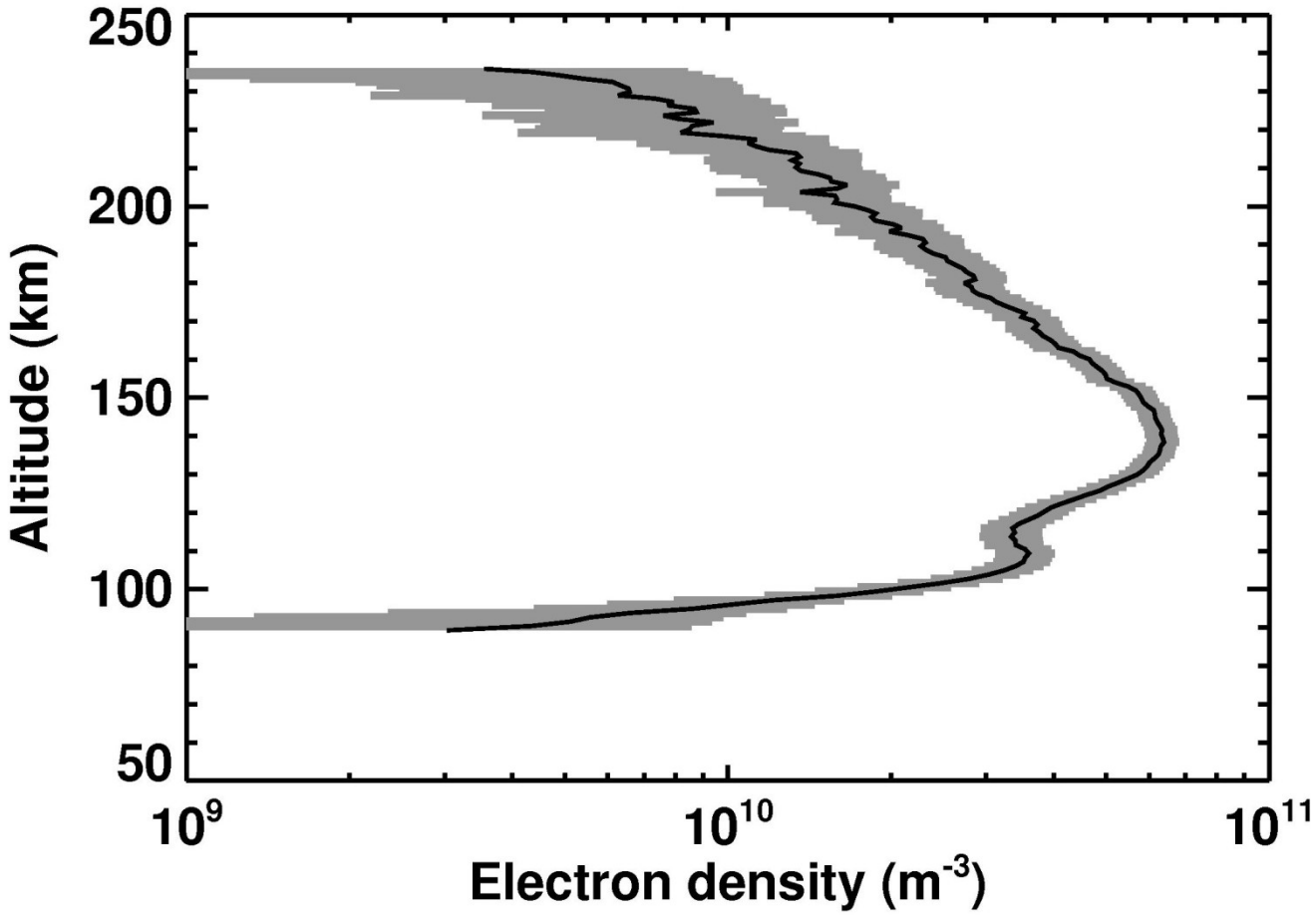



Fig 1 of Withers et al. (2008)

# Mars profile with meteoric layer

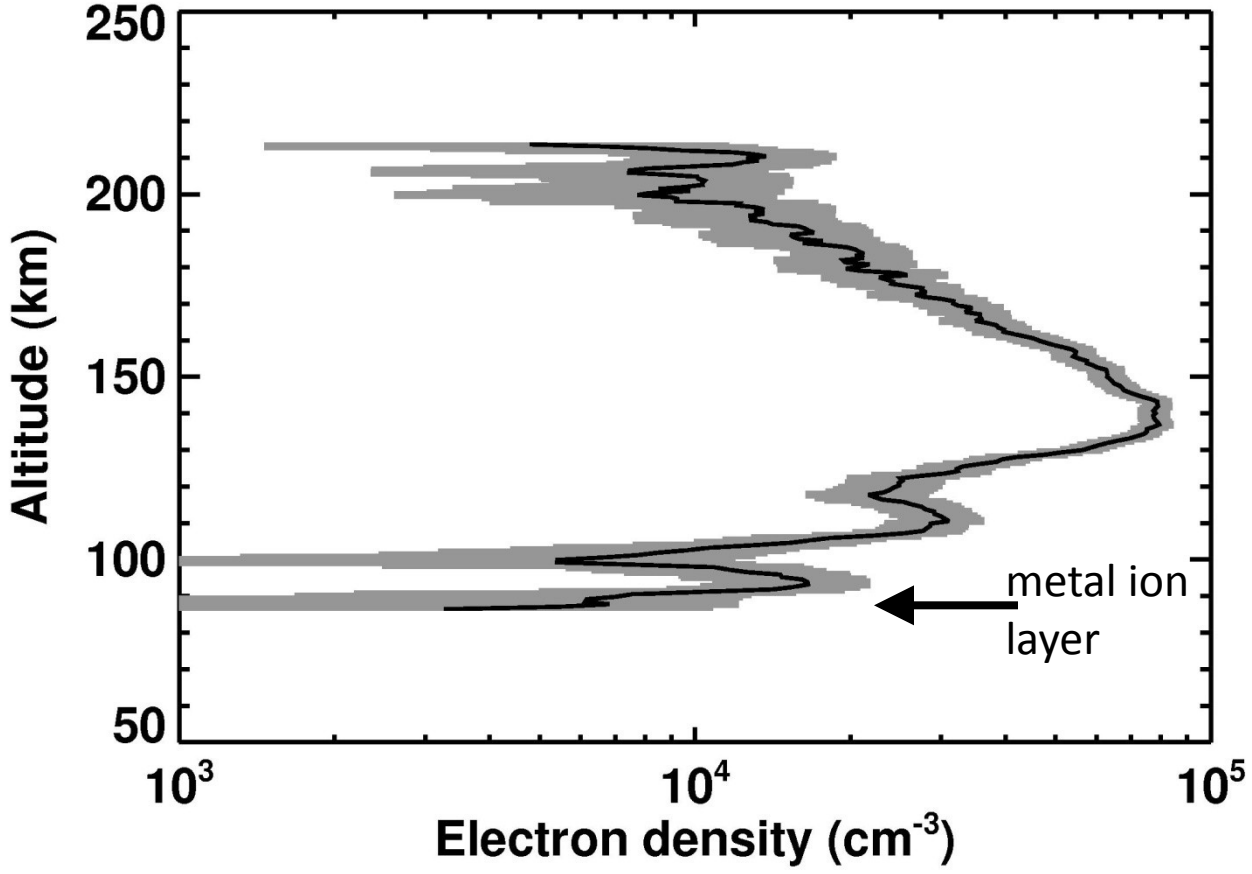
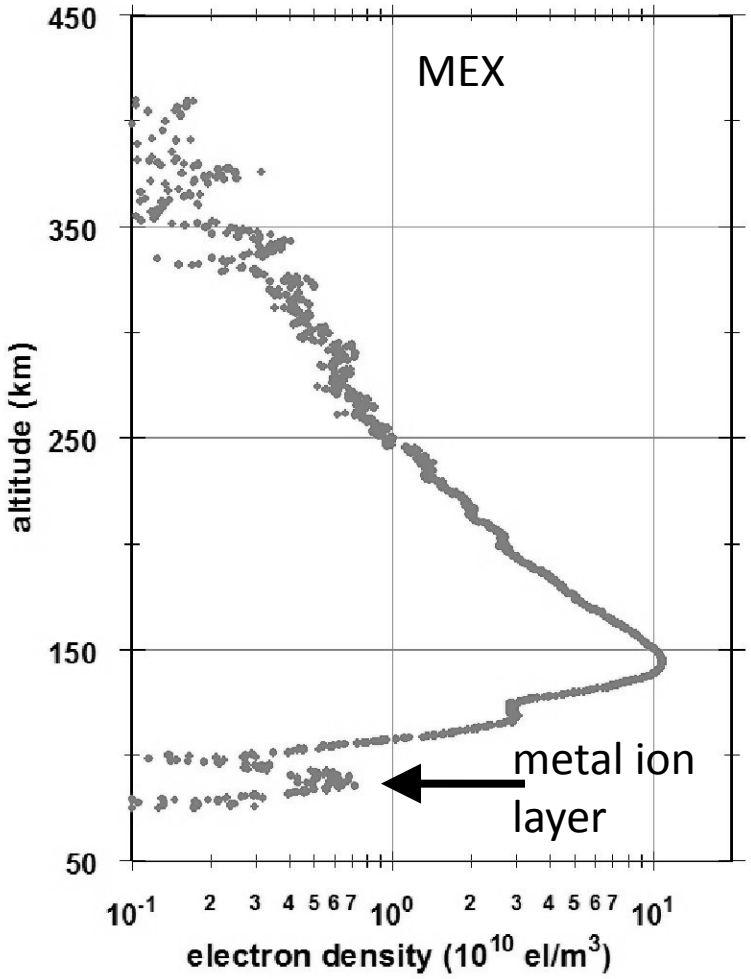



Fig 2 of Withers et al. (2008)

# Another Mars example




On Mars, meteoric layers are relatively broad (10 km), have a typical observed density of $10^4$ cm$^{-3}$, and occur at 90 km (~0.01 Pa) altitude. Meteoric layers are found only sporadically on Mars.

# Model prediction for Mars

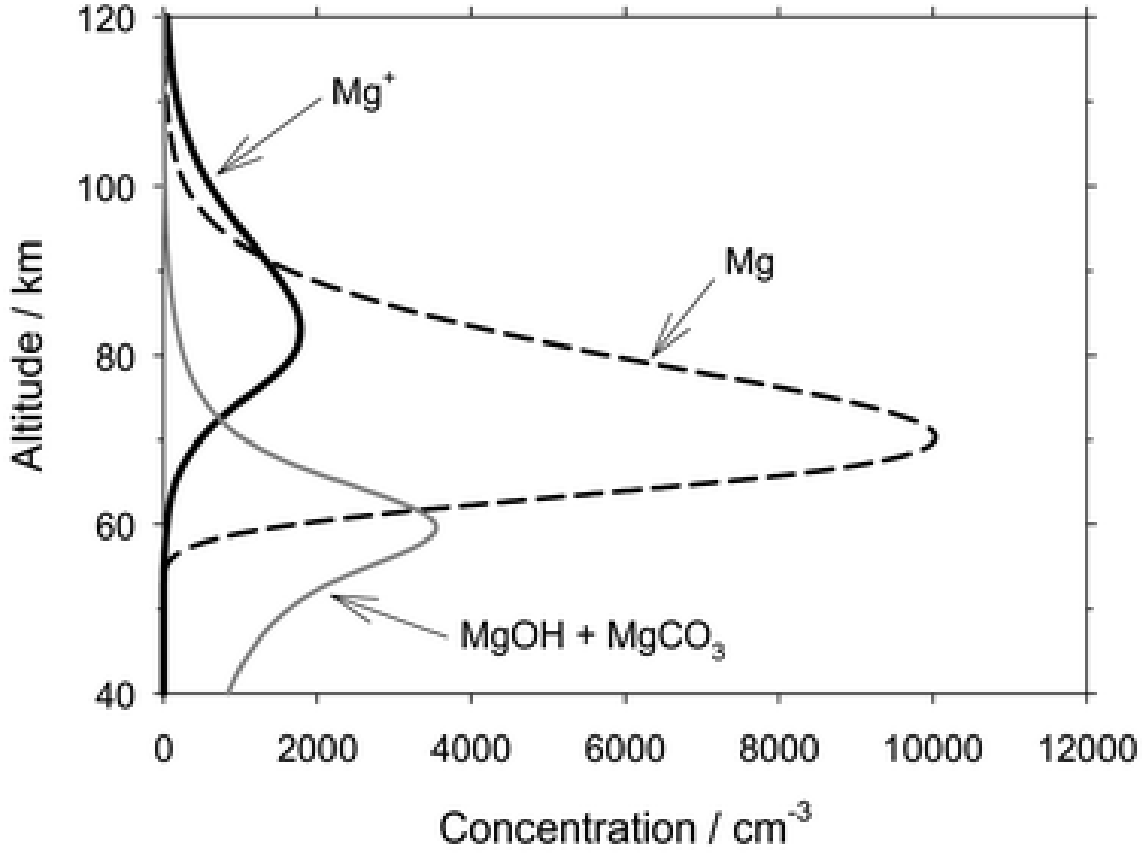
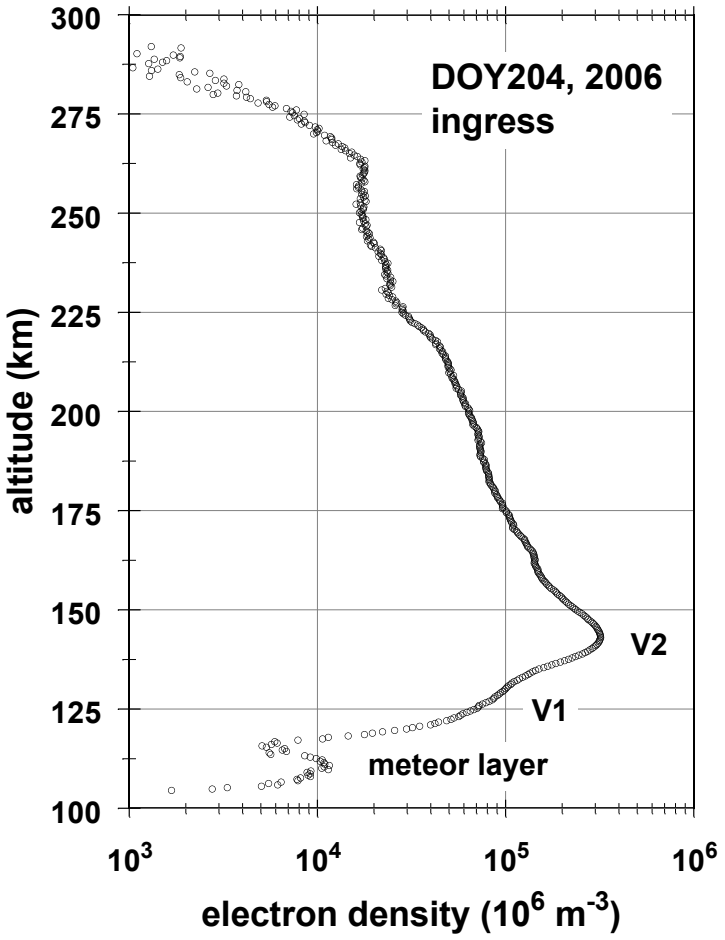



Fig 11 of Whalley and Plane (2010)

# Venus profiles:
# With and without meteoric layers



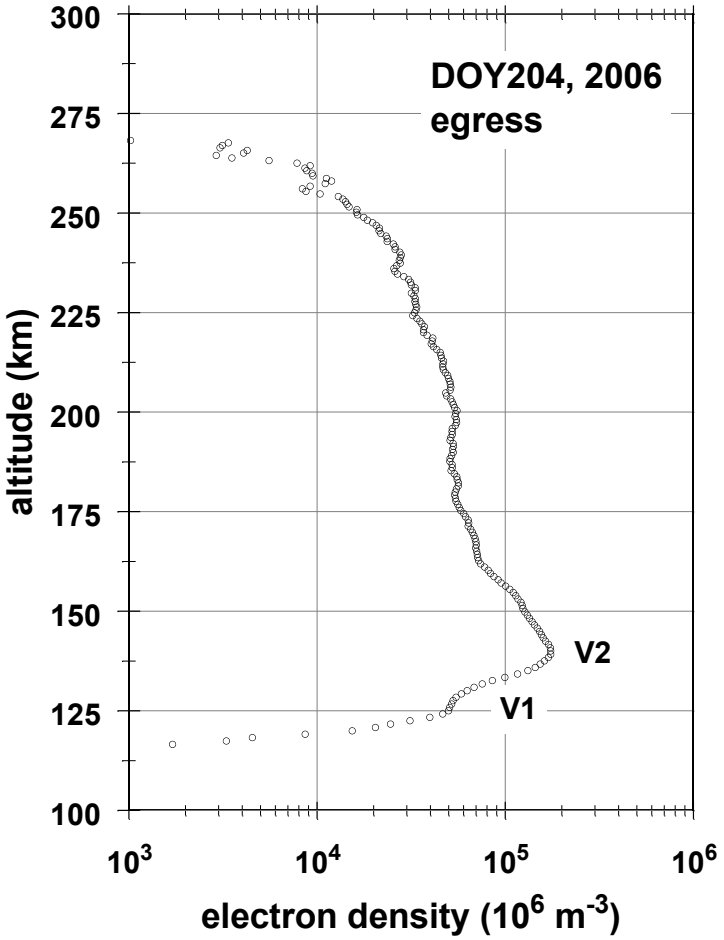




Fig 1 of Paetzold et al. (2009)

# More Venus examples

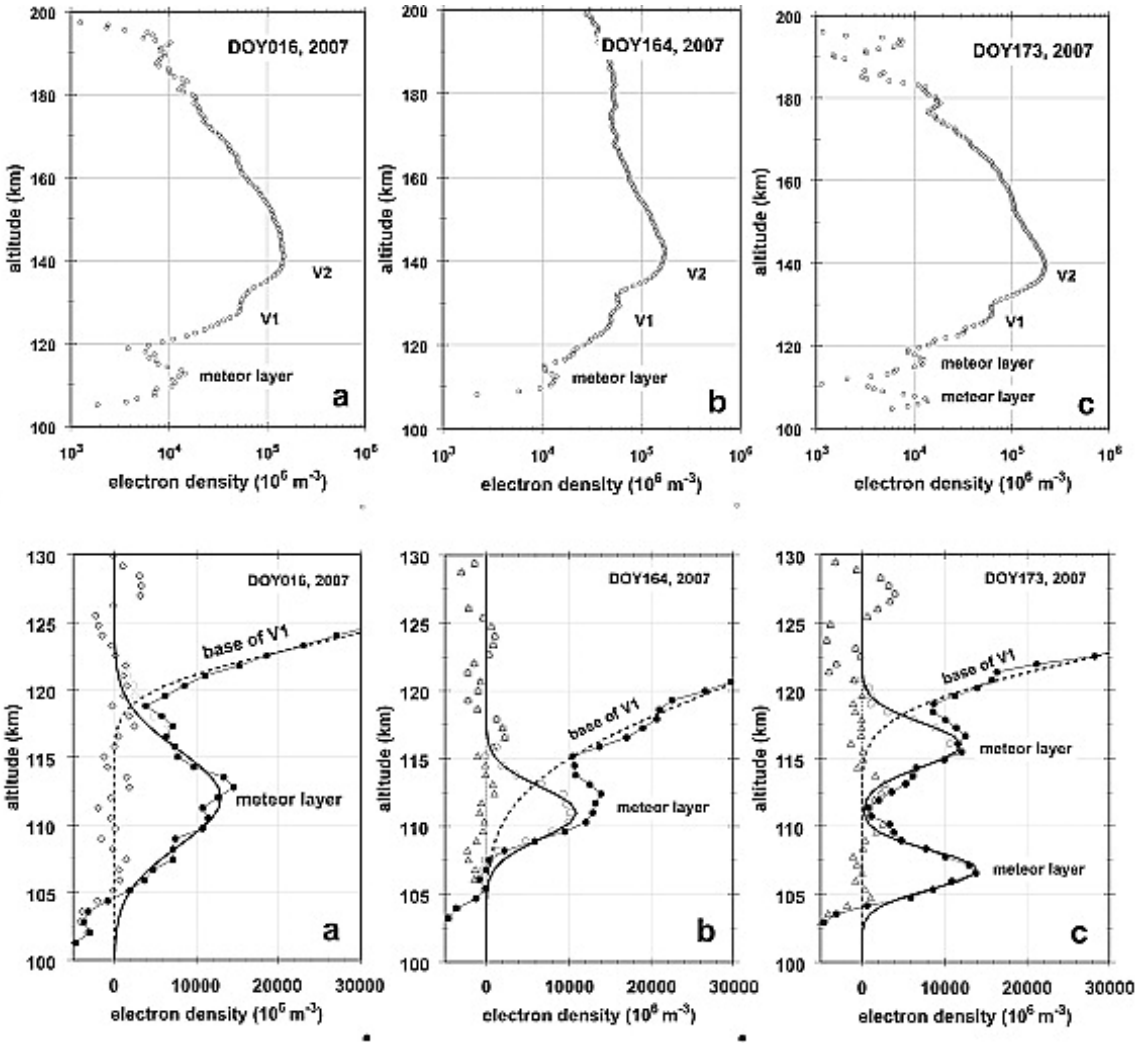
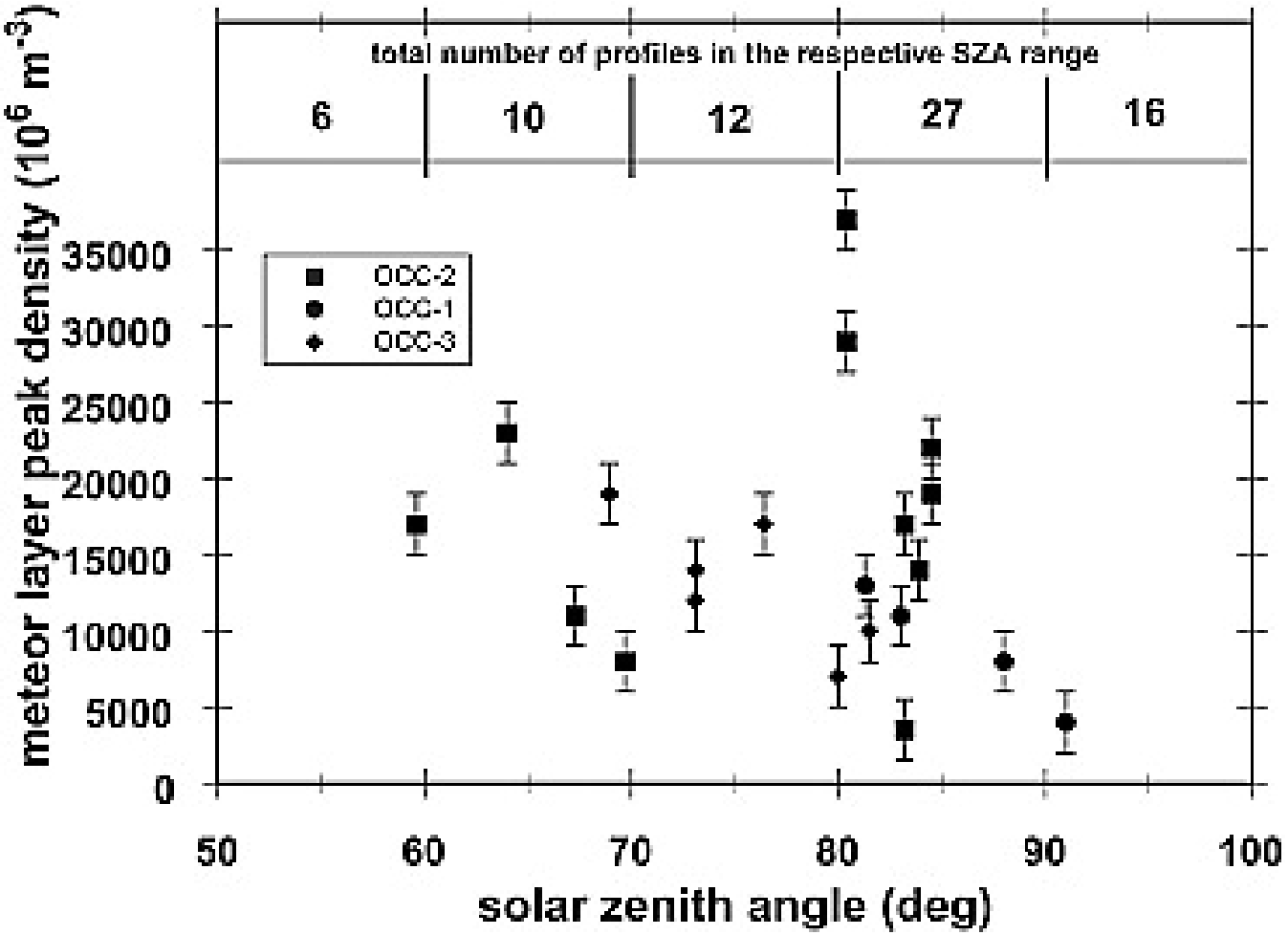



Fig 2 of Paetzold et al. (2009)

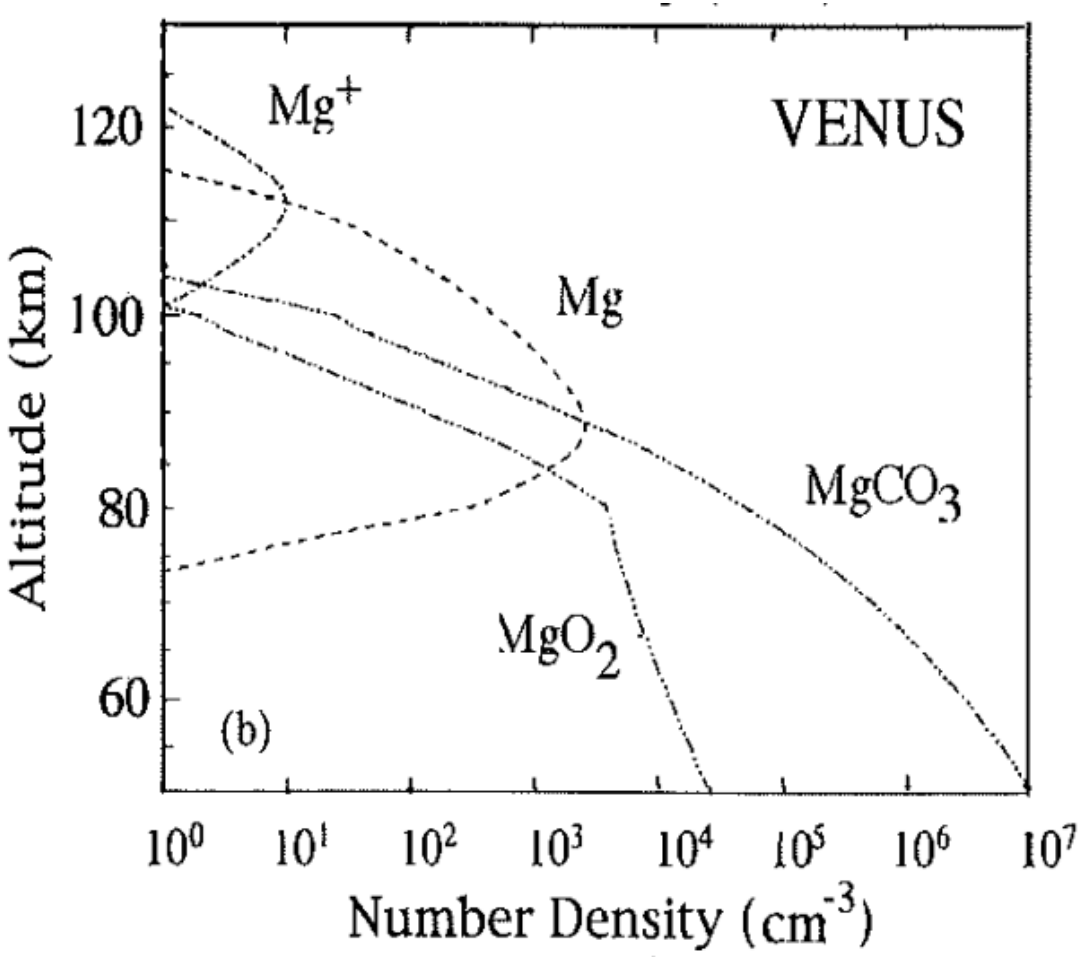
# Occurrences of layers on Venus




Is absence of layers at SZA < 60$^o$ real?

Fig 3 of Paetzold et al. (2009)

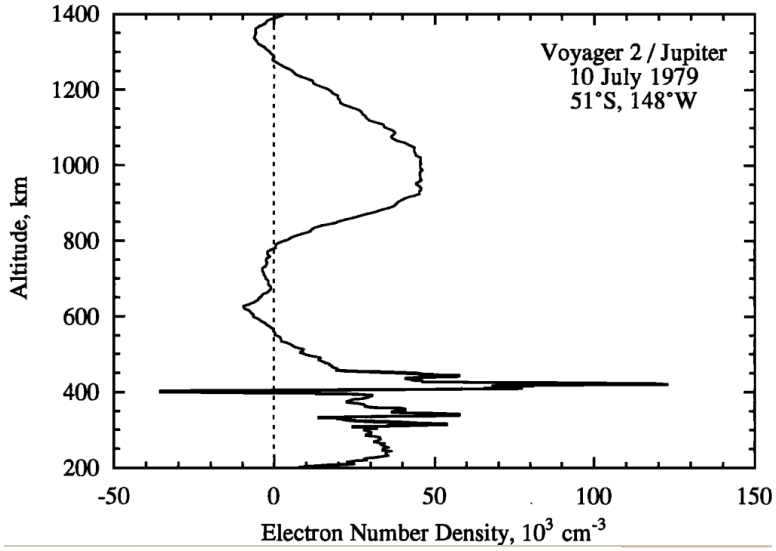
# Model prediction for Venus




Significant improvements needed

Fig 2b of Grebowsky et al. (2002)

# Metal ion layers at Jupiter? Data

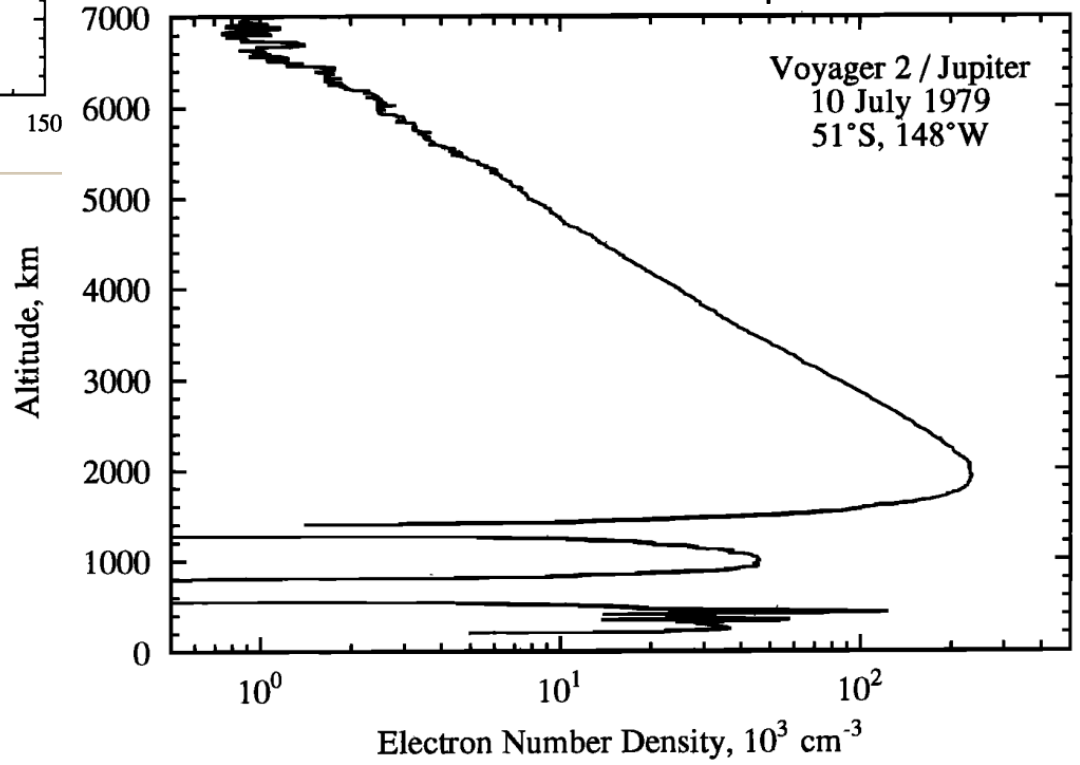



Low altitude portion of profile

Narrow layers near 400 km may be metal ion layers

Full profile

$H^+$ peak at 2000 km
$H_3^+$ peak at 1000 km
Metal ion peak at 400 km?




Figs 4 and 5 of Hinson et al. (1998)

# Metal ion layers at Jupiter? Model

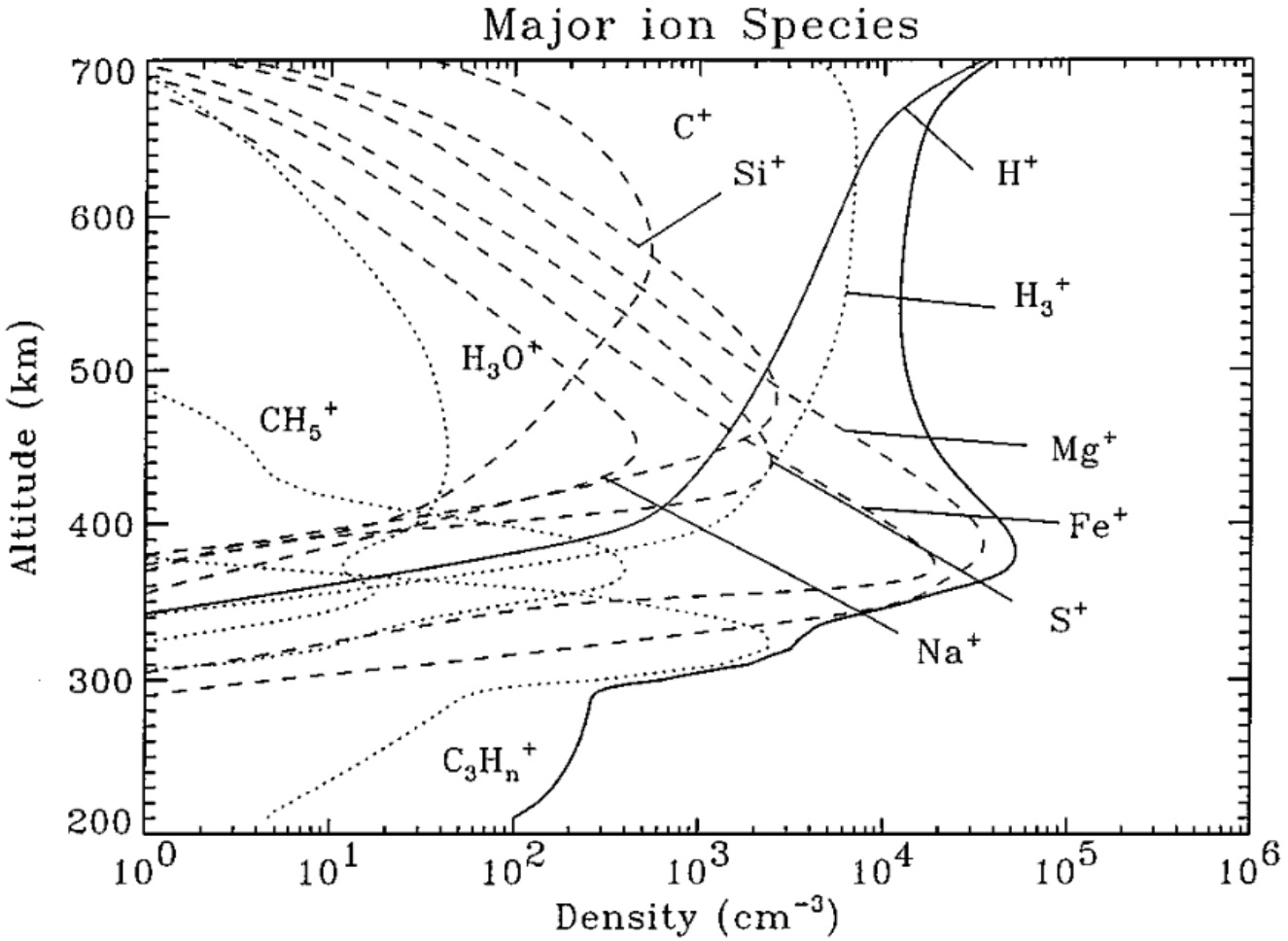
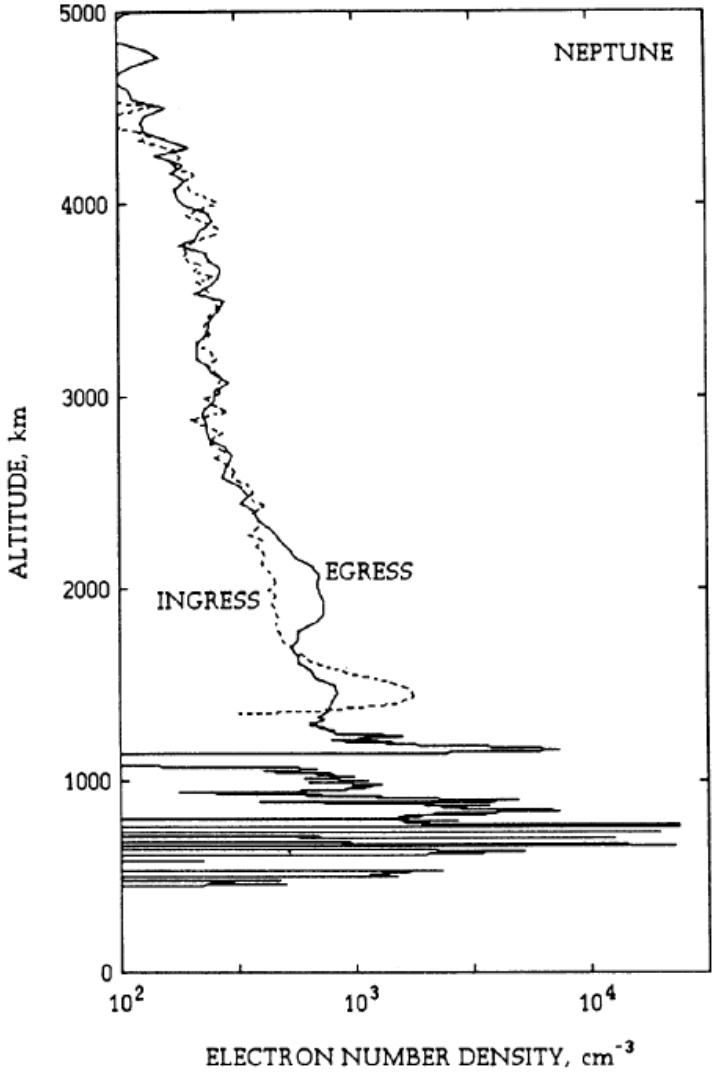
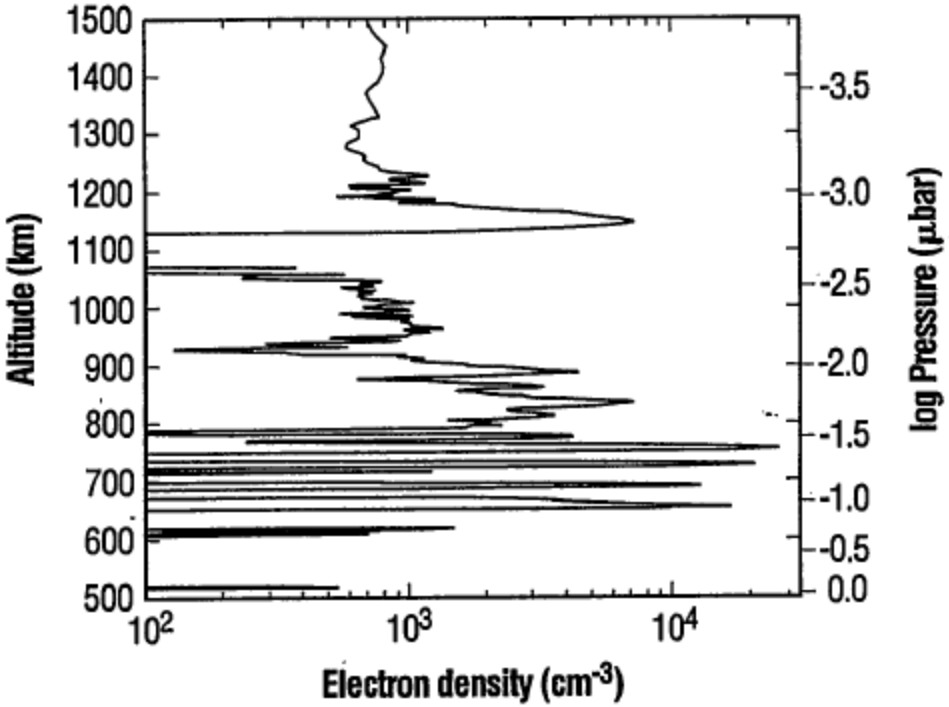



Fig 3 of Kim et al. (2001)

# Metal ion layers at Neptune? Data




Full profile Fig 8 of Lindal (1992)




Low altitude portion of egress occultation
Narrow layers at 600-800 km may be metal Ion layers Fig 2 of Lyons (1995)

# Metal ion layers at Neptune? Model

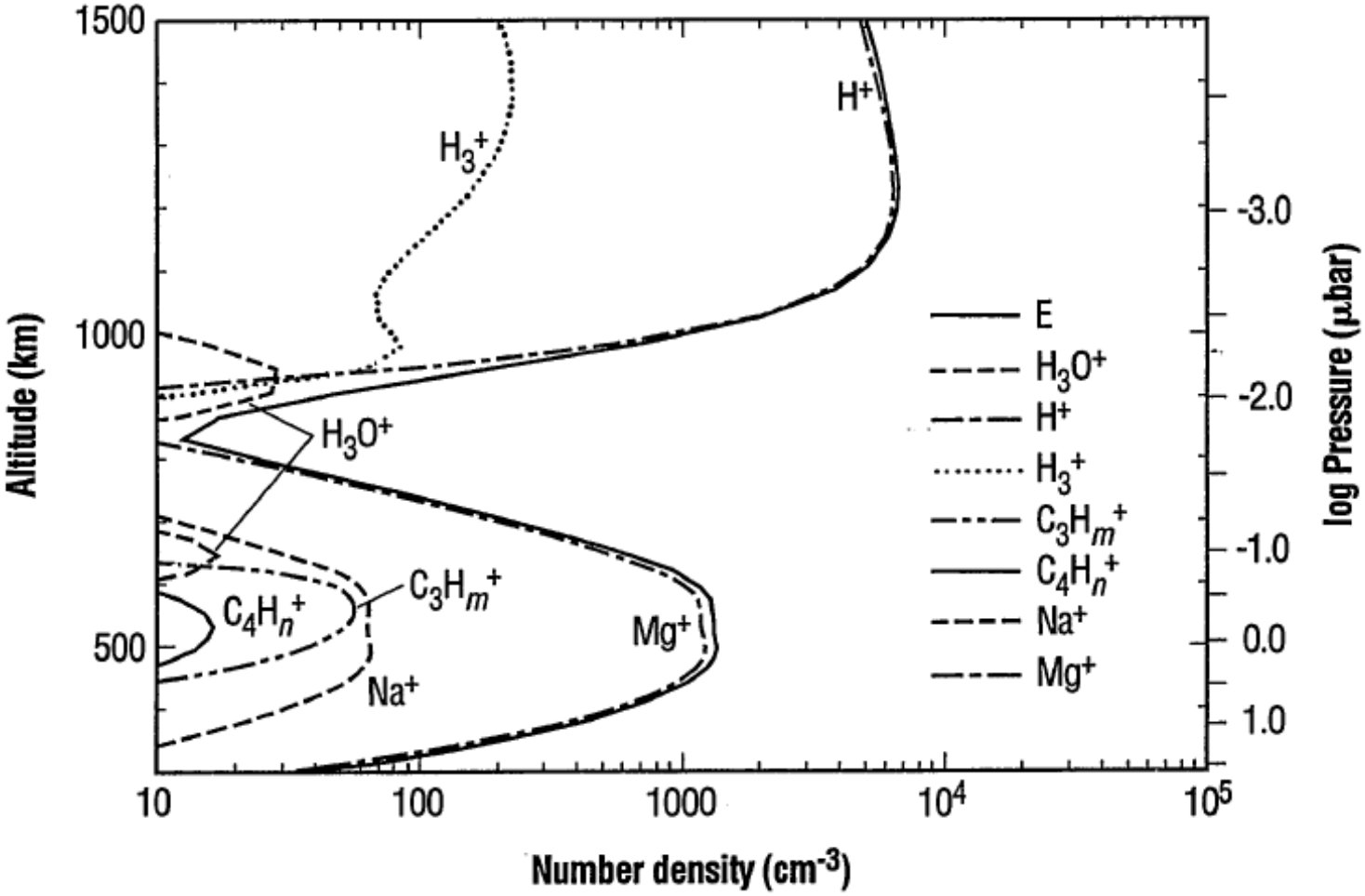



Fig 4 of Lyons (1995)

# Outstanding questions

- How similar are the major chemical and dynamical processes at Venus and Mars to the major processes at Earth?
- What is the meteoroid flux at other planets?
- Are putative detections in the outer solar system real?